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TITLE: COST DATA BASE DEVELOPMENT  
A TWELVE-YEAR PERSPECTIVE

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## INTRODUCTION

There are three prerequisites for cost estimating research and analysis to have a meaningful impact on the decision making process in any public agency or private enterprise. They are:

- . Policy
- . Methodology and Tools
- . Credible Data

These prerequisites form a triad for effective decision making. Together they account for the necessary and sufficient conditions upon which good recommendations and decisions can be made. If either of the three are missing or weak, then we are bound to draw faulty conclusions and make less than optimal decisions.

A policy is needed that recognizes there is no free lunch. Weapon systems like any other commodity are being developed, procured and fielded in a resource constrained environment. Official decision making policy, practices and procedures should comprehend this imperative and establish a framework for rationally evaluating resource trade offs and military worth or utility.

At the same time, rigorous, defensible and reasonably sophisticated methodological approaches and evaluation tools are necessary. These tools should enable analysts and decision makers to conduct cost and economic research within the policy framework; lead to results and conclusions which are understandable at any echelon in the decision making establishment; and allow any interested party to repeat the analysis and come out with the same results.

The third leg of the triad is data. Data must be partitionable in the infinite number of ways that questions arise in the policy and decision making establishment. It also must be clean and valid before it is used in the numerous tools and models of our cost estimating and analysis profession.

The intent of this paper is to investigate the vigor and health of this cost analysis triad within the Defense Department. This investigation reflects an awareness of cost analysis policy development over the past two decades as well as an insight into the development of cost estimating methodologies and tools over a 25 year period. The strength of the data leg of the triad is also investigated, albeit, from a somewhat more introspective point of view.

## POLICY DEVELOPMENT

1961 was a turning point for the thenceforth growing impact of economists and cost analysis in the Defense Department. Cost analysis, cost effectiveness and program budgeting started on their long, uphill journey towards becoming prime elements in the decision making process. These concepts, derived primarily from the thinking of Charles Hitch, were implemented by Robert McNamara when he was appointed Defense Secretary in 1961. First heralded the Program Change Control system, the Planning, Programming and Budgeting System (PPBS) as we know it today was born.

Prior to this time, the Defense Department developed its force structure by starting with a budget and then seeking out possible programs. There was no pragmatic way of relating costs to weapons systems, tasks and missions. Time phased costs of proposed programs were not known, studied or rigorously analyzed. Data needed to assess properly the costs or effectiveness of alternative programs was not available.

Within this basic framework, cost estimating and analysis requirements began to be defined as key policy and decision making variables. Some of the important milestones in the development of the policy framework include:

- 1962 - The Program Change Control System  
Department of Defense Directive 7045.1
- 1964 - Integrated Logistic Support  
Department of Defense Directive 4100.35
- 1966 - Resource Management Systems of the DoD  
Department of Defense Directive 7000.1
- Cost Information Reports  
Department of Defense Instruction 7041.2
- 1968 - Work Breakdown Structures for Defense Material Items  
Department of Defense Directive 5010.20
- 1969 - Economic Analysis and Program Evaluation for Resource Management  
Department of Defense Instruction 7041.3
- The Planning Programming and Budgeting System  
Department of Defense Instruction 7045.7
- 1970 - Life Cycle Costing Procurement Guide; LCC-1  
- Life Cycle Costing Procurement Guide; LCC-2
- 1971 - Major System Acquisition  
Department of Defense Directive 5000.1
- 1972 - Selection and Acquisition of ADP Resources  
Department of Defense Instruction 4105.55
- 1973 - OSD Cost Analysis Improvement Group  
Department of Defense Directive 5000.4
- Life Cycle Costing Procurement Guide; LCC-3
- Design to Cost  
Department of Defense Directive 5000.28
- Contractor Cost Data Reporting  
Department of Defense Directive 7000.11

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- 1974 - Level of Repair Analyses  
Military Standard 1390
- Assistant Secretary of Defense (Policy Analysis and Evaluation)  
Department of Defense Directive 5141.1
- 1975 - Major System Acquisition Procedures  
Department of Defense Instruction 5000.2
- Selected Acquisition Reports  
Department of Defense Directive 7000.3
- 1976 - Selection of Contractual Sources for Major Defense Systems  
Department of Defense Directive 4105.62
- OMB Circular A-109
- DoD Value Engineering Program  
Department of Defense Directive 5010.8
- 1977 - Performance Measurement for Selected Acquisitions  
Department of Defense Instruction 7000.2
- Defense Production Management  
Department of Defense Directive 5000.34
- Uniform Budget/Cost Terms and Definitions  
Department of Defense Instruction 5000.33
- 1978 - Assistant Secretary of Defense (Program Analysis and Evaluation)  
Department of Defense Directive 5141.1
- 1979 - Selected Acquisition Reports  
Department of Defense Instruction 7000.3
- 1980 - DoD In-House versus Contract Commercial and Industrial  
Activities Cost Comparison Handbook  
Department of Defense Handbook 4100.33
- Acquisition and Management of Integrated Logistic  
Support for Systems and Equipment  
Department of Defense Directive 5000.39
- Reliability and Maintainability  
Department of Defense Directive 5000.40

Together, these policy statements define a comprehensive framework of analysis drawing attention to the importance of cost as a key decision making variable. And of course, each of the services have reflected these policies within their own instructions on a fairly consistent basis.

Department of Defense Directive 7045.1, "The Program Change Control System," (12 April 1962) provided initial policy guidance and established a structure for submitting and monitoring changes to the Five Year Defense Program (FYDP). This directive addressed the need within the DoD to make program costs more visible and thus easier to control. The information required by DoDD 7045.1 enabled SECDEF to assess and evaluate the relative costs and merits of alternative programs. DoD Instruction 7045.7, "The Planning, Programming and Budgeting System," (29 October 1969) revised and updated DoDD 7045.1 to make it even more responsive to SECDEF cost analysis requirements. The procedural guidance provided in this later instruction (including detailed instructions for preparing Program Change Requests (PCR's), Program Objective Memorandum (POMs), Program Change Decision (PCD) and Program Budget Decision (PBD) Papers) facilitates "the submission, analysis, review and approval of DoD programs and budgets". DoDI 7045.7 also explained in detail the mechanics of the PPBS schedule and how it provides input into the FYDP. In 1975, the Secretary of Defense issued DoDI 7000.3 "Selected Acquisition Reports". This instruction provides standardized formats and directions for reporting comprehensive summary level costs, quantity, schedule and technical information on major systems to the Secretary of Defense.

Recognition of the importance of controlling costs through increased visibility and cost/economic analysis was not limited to the more aggregate program justification levels; the Defense Department also realized the necessity of controlling costs within the individual programs. Thus, the Secretary of Defense and the Joint Logistics Commander (JLC) issued several directives, instructions and guides which provided program managers within the services with guidance and methodology for performing cost and economic analyses of both ongoing and proposed programs. These include DoDD 5010.20 "Work Breakdown Structures for Defense Material Items" (accompanied by Military Standard 881, "Workbreakdown Structures for Defense Material Item), DoDI 7041.3, "Economic Analysis and Program Evaluation for Resource Management", the Life Cycle Costing Procurement Guides (LCC-1, 2 & 3), and the Design to Cost Guides, as well as several directives addressing the procurement and acquisition of major defense systems. Together these directives, instructions, standards and guides established cohesive policy guidance and the analytical framework in which DoD components could effectively perform cost, and economic analyses. In general each of the policy elements provide detailed instructions and methodology for performing the required analyses as well as identifying the responsible offices. The mandatory character of the directives ensured more rapid compliance.

In order to facilitate implementation and monitor the progress of defense cost and economic analysis policy, the Secretary of Defense established several working organizations. Among these are the office of the Assistant Secretary of Defense (Program Analysis and Evaluation) OASD, (PA&E), the OSD Cost Analysis Improvement Group (CAIG) and the Defense Economic Analysis Council. The purpose of these groups is largely advisory, with policy making analysis, methodology development, and communications responsibilities.

## METHODOLOGY DEVELOPMENT

Descriptions and specification of pragmatic methodologies and tools to conduct the analysis required by the policies noted above are abundant. The techniques for performing cost analysis, cost effectiveness and budget estimating are straightforward. As policy requirements have evolved, there has been a complimentary effort in the literature to translate state of the art forecasting and estimating techniques to specific applications within the Defense Department. Much of this applied research has come out of the Federal Contract Research Centers such as RAND and GE TEMPO. A representative sampling of this documentation includes:

- Weapon Systems Cost Analysis; G. Fisher; July, 1956.
- Economics and Military Operations Research; Charles Hitch; August, 1958.
- Procedures for Development of a Weapon System Cost Methodology for Navy Weapons; Donald Clegg; May, 1959.
- Use of the Learning Curve; D. Novick; November, 1961.
- Costing Concepts for the Defense Programs Management System; David Curry; March, 1962.
- Project Estimating by Engineering Methods; P. Gallagher; 1965.
- An Introduction to Equipment Cost Estimating; J. Large; January, 1968.
- Life Cycle Cost Modeling; J. Hamilton, Army Material Command; December, 1968.
- Life Cycle Costing in System Acquisition; Logistics Management Institute; November, 1969.
- A Generalized Life Cycle Cost Model for Electronic Equipment; Booz, Allen and Hamilton; March, 1970.
- Cost Management Methods; Booz, Allen and Hamilton; March, 1971.
- Costing Methodology Handbook; Office of the Comptroller of the Army; April, 1971.
- Guidelines for Cost Estimation by Analogy; C. Trigg, U.S. Army Electronics Command; 1973.
- Models and Methodology for Life Cycle Cost and Test and Evaluation Analysis; Richard Anderson; July, 1973.
- AFLC Operations and Support Cost Model; AFSC, AFLC Wright Patterson AFB; October, 1973.

- Navy Weapons System Life Cycle Cost Model; Naval Weapons Engineering Support Activity; September, 1974.
- Logistics Support Cost Model User's Handbook; AFLC/MMOA, Wright Patterson AFB; February, 1974.
- Life Cycle Cost Model; Thomas Otto, Army Electronics Command; July, 1975.
- Life Cycle Cost Model; Joint Tactical Communication Office, TRI-TAC; 1976.
- TRI-TAC Life Cycle Cost Model; Joint Tactical Communications Office; 1978.
- NAVELEX Life Cycle Cost Model; Naval Electronics Systems Command, Cost Analysis Group; 1978.
- TRI-TAC Life Cycle Cost Model; Joint Tactical Communications Office; September, 1981.

The above documents provide only a brief sample of the extensive amount of study and research in the areas of cost and economic analysis. Nonetheless, they serve to illustrate the development and evolution of cost analysis methodology over the past 26 years.

During the late 1950's and into the 1960's cost estimating methodology was relatively simplistic and limited to specific applications. Integrated and comprehensive life-cycle cost analysis methodology as we know it today, was not available to DoD decision makers.

Charles Hitch in Economics and Military Operations Research indicated, military and the government officials frequently approached an acquisition with a requirement analysis. In this scenario, staff officers would establish a set of "required" tasks or performance characteristics based on "military judgement" or "needs"; cost considerations were typically excluded from the initial analysis. Costs were later computed in terms of budget, or manpower required to meet the performance parameters, e.g., costs analysis was an outgrowth of the requirements analysis. Even at this early date, Hitch argued for the application of operations research and economic analysis to major defense acquisition decisions.

The growing importance of inflation and budgetary considerations during the 1960's was reflected in increasing requirements of DoD policy and guidance. These development in turn encouraged both the development and implementation of more sophisticated cost-estimating methodologies. The U.S. Air Force was a pioneer in the field of weapon systems cost analysis. In order to more accurately predict system acquisition costs, the Air Force (followed shortly by the other services) introduced several methodologies including:

- . learning curve analysis
- . statistical regression analysis
- . industrial engineering standards
- . rates and factors
- . specific analogies
- . estimating relationships

A thorough discussion of these and other approaches to cost-estimating appears in the Air Force Systems Command Manual "Cost Estimating Procedures" dated 28 November 1967, as well as several other of the previously referenced documents. The development and refinement of these methodologies represent a substantial contribution to the field of cost analysis. However, these seminal techniques concentrated on controlling production costs. As cost analysis achieved widespread application, cost estimators recognized the need for a tool or process which would both bring together the different estimating elements and enable the government to determine the total cost of an item or system over its full life.

The DoD concept of Life Cycle Cost evolved in the late 1960's to meet this requirement. Life Cycle Costing may be defined as "the process of listing or determining the individual costs of an item or system from development and production costs, through operating and support cost, to and including disposal costs." The late 1960s and early 1970s witnessed the development of several life-cycle cost models (LCCMs). These models were based on work breakdown structures which disaggregate the system to subsystem and component levels and a cost breakdown structure which disaggregates cost. These LCCMs accounted for time phasing of costs, and inflation among other relevant issues. In general, these early models were not automated, and were oriented toward particular equipment groups, e.g., aircraft, electronics gear, artillery. Furthermore, earlier models concentrated on estimating production costs while addressing development and support costs to a lesser degree of sophistication.

Throughout the 1970s, DoD LCC policies became more oriented to controlling operations and support costs as reflected by the several directives dealing with logistics management. Additionally, there was a concerted effort to make the LCCMs more generic and useable. Consequently, recent LCCMs have become increasingly comprehensive, addressing all phases of the equipment life-cycle with a significant degree of sophistication. In general, these LCCMs exhibit a much wider degree of application than their predecessors, both in terms of the ability to handle a variety of equipment types and useability; models are automated and allow the user substantial flexibility in the choice of cost elements, time phasing, and estimating relationships. For example, the most recent revision of the TRI-TAC LCCM lists the following characteristics:

- . Interactive feature
- . Easy access to multiple users -  
with user confidentiality and data access controls



- Cost element structure -  
with costs element definitions
- Incorporated data base -  
default values for assumptions, pay data,  
maintenance scenarios
- Costing modules -  
inflation/discounting, change base year, phase  
spending rates
- Diversity of output reports -  
LCC, DTUPC, Annualized Cost, POM
- Data collection workbook and record book -  
for audit trail; for recording sources, assumptions,  
working notes

Although this list by no means exhausts the capabilities of the TRI-TAC LCCM, it serves to illustrate the versatility of the model.

In sum, cost and economic analysis methodology has improved significantly in the past 20-25 years, in response to the changing needs of the DoD economic environment. The ability to estimate program costs has evolved from simple requirements analyses in the late 1950s to acquisition cost estimating methodologies in the 1960s, to comprehensive life cycle cost models in the 1970s and 1980s. However, these models are only as accurate as the data used. If a model has to work with insufficient, inaccurate or grossly exaggerated data, it can be expected that the model will generate similarly inaccurate and unacceptable results.

#### DATA AND DATA BASES

Booz, Allen has been involved in the conduct of cost analysis research for the Department of Defense since the formation of a subsidiary devoted to providing consulting services to the federal government in 1955. This part of the analysis reflects our experience with respect to the existence, quality and availability of relevant cost information and data with which to carry out particular research efforts. While not totally comprehensive in terms of all the studies which have been conducted both within the Defense Department or the consulting industry, our experience does represent a good cross section of efforts that have been made.

The criteria used to evaluate the data that we have used over this period are threefold:

- Quantity
- Quality
- Access

By quantity, we are referring to the mere existence of return cost information for existing systems and equipments. The classical approach used in conducting an economic analysis for proposed systems and concepts is to go to various data repositories and pull information together that will answer the question -- How much did it cost the last time we did it? -- and then extrapolating the required estimate from this data base, using the methodologies and techniques described previously. Of course, partitioning of this information is a critical aspect of the nature of the answer. As policy and methodologies have evolved, data requirements have become ever more granular and finely divided. A cost element structure of 2-3 elements in 1960 has given way to analyses which in some cases require more than 1000 discrete elements in the 1980s.

The quality dimension addresses the inherent character of each data point. Here we are concerned about the accuracy, validity and reliability of data being used in particular economic analyses.

The third criterion has to do with availability. Given that information of some utility to the cost analyst exists, what kind of access does the research team have to data. Timeliness is also a consideration.

With this perspective, the assessment of data and data bases is made by evaluating quantity, quality and access to cost information used to conduct five studies since 1968.

- 1968 - Armored Reconnaissance Scout Vehicle
- 1969 - Multiplexers, Radio Combiners and Cable Combiners
- 1978 - Over-the-Horizon Detection, Classification and Targeting
- 1979 - Landing Vehicle Tracked - Experimental
- 1981 - Electronic System Operating and Support Cost Data

For each of these cost studies, an evaluation of the data is presented using the criteria discussed above.

1. Armored Reconnaissance Scout Vehicle (XM 800) Parametric Design/Cost Effectiveness Study - 1968 U.S. Army Tank Automotive Command

QUANTITY	QUALITY	ACCESS	QUANTITY	QUALITY	ACCESS	QUANTITY	QUALITY	ACCESS
POOR	POOR	FAIR	GOOD	FAIR	FAIR	POOR	POOR	POOR
XXX			XXX			XXX		
RESEARCH DEVELOPMENT			INVESTMENT			OPERATIONS AND SUPPORT		

This was a fairly extensive effort finally documented in eight volumes addressing requirements synthesis for various operational scenarios and simulations, development of specific design and performance characteristics and the conduct of analysis leading to the selection and recommendation of a candidate conceptual vehicle. A detailed life cycle cost estimate for the

candidate, eight alternative configurations and six reference vehicles already in the operating inventory was prepared. The search for data encompassed Army cost records, vehicle system manufactures, and subsystem manufactures. Visits were made to six firms to obtain data, with meager results due to the competitive environment and the proprietary nature of the information. Subsystem data was obtained for current production items. Data for this study is rated in all three areas: research and development; production; and operation and support. Five of the nine ratings are poor reflecting lack of data or access. The Army did have good production cost data on the reference vehicles, but all other elements were eventually estimated using elements of production cost as the dependent variable and a set of forty detailed assumptions. In the operation and support area, the response to requests for historical data was generally of the nature -- "When you find out what that costs, I would like to know!"

2. Acquisition Cost Model for Multiplexers, Radio Combiners and Cable Combiners - 1969 U.S. Army Electronics Command

QUANTITY	QUALITY	ACCESS	QUANTITY	QUALITY	ACCESS	QUANTITY	QUALITY	ACCESS
			FAIR	FAIR	POOR			
NOT APPLICABLE			XXX			NOT APPLICABLE		
RESEARCH DEVELOPMENT			INVESTMENT			OPERATIONS AND SUPPORT		

The objective of this study was to develop cost estimating relationships and algorithms for all aspects of the investment phase for various multiplexers, radio combiners and cable combiners. After lengthy delays, contractual data on nine competitive and sole source contracts awarded in the late 1960s representing three contractors was obtained for analysis. The intention at this point was to derive estimators for all elements of the DD633, in itself a significant change in scope from the original objective. The focus was now to look at contractor bids as opposed to actual return data for all of the contractor and government cost elements associated with the investment phase.

Review of the DD633s revealed significant differences in the way contractors roll up their bids; and a number of judgemental adjustments were required in order to normalize the data. Even so, the final result was limited to specifying a model for estimating unit production costs, and the conclusions point out the utility of the model was limited by the data base used in the study. As an aside, it took over six months to access and obtain the contractual documents.

3. Over-the-Horizon Detection, Classification and Targeting - 1978  
Naval Electronic Systems Command

QUANTITY	QUALITY	ACCESS	QUANTITY	QUALITY	ACCESS	QUANTITY	QUALITY	ACCESS
FAIR	FAIR	FAIR	GOOD	FAIR	GOOD	GOOD	FAIR	FAIR
XXX			XXX			XXX		
RESEARCH DEVELOPMENT			INVESTMENT			OPERATIONS AND SUPPORT		

The objective here was to prepare an independent cost estimate of the remaining research and development, investment and support costs associated with fielding an initial Over-the-Horizon Detection Classification and Targeting capability to support deployment of the TOMAHAWK.

Development efforts had been ongoing for sometime and the required capability was reasonably well defined. Investment requirements were specified in the form of detailed equipment lists and part numbers, and vendors, eager to participate in the program, readily supplied price quotes for various quantities of off the shelf components. These were verifiable from other sources including GSA catalogs. Here again, the operation and support phase was the least well defined, particularly in the maintenance and software support areas. In sum, the quantity and quality of data available had improved over the intervening ten years, and access to the information was facilitated by the competitive interest in providing many of the standard components. This improved assessment derives primarily from the specificity of performance requirements and objectives.

4. Conceptual Design for the LVT(X) - 1979  
Naval Sea Systems Command

QUANTITY	QUALITY	ACCESS	QUANTITY	QUALITY	ACCESS	QUANTITY	QUALITY	ACCESS
FAIR	FAIR	POOR	GOOD	FAIR	POOR	GOOD	GOOD	FAIR
XXX			XXX			XXX		
RESEARCH DEVELOPMENT			INVESTMENT			OPERATIONS AND SUPPORT		

This study provides a very direct comparison with the 1968 effort for the U.S. Army Tank Automotive Command. This effort also included a requirements synthesis for alternative operating scenarios, specification of design and performance characteristics and recommendations concerning a candidate conceptual vehicle.

The cost estimating and analysis requirements for this concept design effort stand as a testament to the growth of economic analysis policy in the Defense Department. Life Cycle Costs were required to be estimated for over 40 discrete elements for each of 14 major subsystems over a 21 year period. In addition, there were over 95 elements requiring separate estimates to build up a design-to-unit production cost estimate.

In evaluating the data used on this study it is noteworthy that only two of the nine categories are rated poor. There has been significant improvement in the quantity and quality of information, but gaining access was a significant hurdle. Much of the data actually used was finally obtained during the fifth month of this six month effort.

5. Electronic System Operation and Support Cost Data Base - 1981  
Naval Electronic Systems Command

5. Electronic System Operation and Support Cost Data Base - 1981  
Naval Electronic Systems Command

QUANTITY	QUALITY	ACCESS	QUANTITY	QUALITY	ACCESS	QUANTITY	QUALITY	ACCESS
						GOOD	FAIR	POOR
NOT APPLICABLE			NOT APPLICABLE			XXX		
RESEARCH DEVELOPMENT			INVESTMENT			OPERATIONS AND SUPPORT		

As noted thus far, that portion of the life cycle suffering most relative to the evaluation criteria used here is the operation and support phase. This is recognized by all of the services and OSD, and a number of efforts are underway to improve the situation. In recognition of this problem, NAVELEX asked us to investigate the feasibility of compiling an operation and support cost data base for a number of the electronic systems they have deployed over the last ten years.

We started out by defining a operation and support cost element structure that included forty-five elements and identified generic information sources from which to obtain the required data.

An assessment was then made of the availability, applicability and quality of data which could be used later to develop cost estimating relationships for the identified cost elements. As a trial run, data was sought for more than 50 variables relating to twenty-six of the cost elements for two electronic systems. We found, through extreme persistence, that it was possible to collect actual data on 36 of 57 variables for one of the systems and 41 of the variables for the other system. This was extremely time consuming. Sources for many of the variables are not readily accessible data base systems, but rather fall within the purview of individual management teams at multiple locations. Where automated systems exist, they tend to have a process or functional orientation rather than a system perspective. For example, the focus is on how many circuit card modules were processed or students trained in total as opposed to being readily traceable to particular types of electronic systems. When this is the case, manual sorting of data is required to bridge the gap.

The next phase focused on key operating and support cost driver elements for a dozen different systems. Simply determining the quantity of each system deployed on an annual basis in an operational status is a difficult hurdle, let alone the construction of accurate repair and provisioning data. Access to existing data is a real issue. It took over nine months to obtain maintenance and material management system data in a format compatible with the specification of annual operational and intermediate support costs. This was eventually obtained in the form of approximately seven feet of tabular reports requiring extensive manual sorting.

## CONCLUSION

Policy developments have been both comprehensive and complimentary to the support of cost-effective decision making in the Defense Department. DoD has implemented more than forty policy directives since the advent of the Program Change Control system in 1962. If we were to count the number of updates and service level directives amplifying these basic policies over the last 20 years we must conclude that a vigorous and healthy policy framework is in place for rationally evaluating resource trade offs.

The same can be said for the methodologies economists employ to conduct cost and economic analysis for the Defense Department. The various models and tools available to us are sufficient to accomplish the job required.

Unfortunately, I think we have a way to go in compiling the data needed to accomplish ~~our~~ various cost estimating and analysis tasks. It is clear to me that data currently exists to answer most questions that arise and that for the most part it is partitionable to the extent required for particular applications. The real issue is one of obtaining the data in a timely manner and of reducing the redundant data collection effort needed every time a cost effectiveness question arises in the decision making arena.

It is time to publish common and statistically sound data like those maintained in other fields of economic research. Other federal departments regularly publish such information that is readily available to interested parties. I submit that the cost of preparing and publishing such data on a regular basis is far outweighed by the current practice of developing unique data for each and every economic question that arises within our community.